# Calibration acceptance plan

*Draft version*

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# 1 INTRODUCTION

The Caloosahatchee Basin Integrated Surface –Groundwater model covers the fresh water part of the Caloosahatchee river basin. It is an integrated model including a suite of model components simulating the flow on overland and in river/canals, flow in the unsaturated and saturated zone, evapotranspiration losses to the atmosphere and an extension to describe the irrigation water use and its distribution.

The MIKE SHE modelling system is applied for the study. It is a multipurpose hydrological model which main feature is integration (full dynamic coupling between the different parts of the hydrological cycle). It is distributed implying that spatial and temporal variation within the model area is accounted for. MIKE SHE is characterized as physically based i.e. measured field data may be entered into the model and the model parameters have a clear physical interpretation.

The primary objective of the model development is to provide a model capable of assessing the impact on the total water budget of the extensive conjunctive use of groundwater and surface water. To predict the impact of various water management initiatives the model should be able to simulate historical records in the water shed. In particular it must represent drought conditions and exceptionally wet years to allow investigation of events occurring at a return period of approximately 10 years.

The performance of the model depends on:

- model conceptualization
- quantity and quality of the basic input data
- model parameters applied and the extent to which they are supported by field data
- the field calibration references available
- the numerical models ability to represent the flow processes.

The calibration process is primarily aiming at obtaining a set of model parameters which provide a satisfactory agreement between model results and field observations. The definition of 'satisfactory' is not clear and must be specified in terms of objective criteria bearing in mind the purpose of the model.

Upon calibration and validation of the model a sensitivity analysis may be undertaken to test how the model responds to certain parameters or input data. Key parameters having a significant effect on model results may be identified and their effect on model uncertainty assessed.

The purpose of the calibration acceptance plan is to discuss the model parameters and input data affecting the calibration process in general and to define calibration targets for the Caloosahatchee Basin Integrated Surface –Groundwater model in particular. The model is calibrated against available observed discharges and groundwater heads. A wide range of outputs may ,however, be derived from the model and apart from objective statistical based criteria the model must be evaluated through the overall capability of representing common hydrological features of the basin, such as flood duration, flood extent , irrigation water demand etc.

# 2 INPUT DATA AND MODEL PARAMETERS

The input data requirements and model parameters for the MIKE SHE model are comprehensive. Each component of the model applies a range of input data types and parameters.

Table 1 provides an overview of input data and model parameters for each model component of MIKE SHE . The parameters may be physically measurable or empirical specific to the equations solved in the model.

| **Model component** | **Model Input** | **Model parameters** |
|---|---|---|
| MIKE SHE SZ – Saturated zone flow | Geological model (lithological information<br>Boundary conditions<br>Drainage depth (drain maps)<br>Abstraction wells and abstraction rate | $K_h$ Horisontal hydraulic conductivity<br>$K_v$ Vertical hydraulic conductivity<br>S , confined storage coefficient<br>S , unconfined storage coefficient<br>Drainage time constant |
| MIKE SHE UZ – Unsaturated zone flow | Map of characteristic soil types<br>Hydraulic Conductivity Curves<br>Retention curves | Ks saturated hydraulic conductivity<br>Θs Saturated water content<br>Θres Residual water content<br>Θeff Effective saturation water content<br>pFc Capillary pressure at field capacity<br>pFw Capillary pressure at wilting point<br>n Exponent of hydraulic conductivity curve |
| MIKE SHE ET – Evapotranspiration | Time series of vegetation Leaf Area Index<br>Time series of vegetation root depth | $C_1$, $C_2$, $C_3$ : Empirical parameters<br>$C_{int}$ : Interception parameter<br>Aroot :Root mass |

| | | |
|---|---|---|
| | | parameter<br>Kc : Crop coefficient |
| MIKE SHE OC – Overland and river/canal flow<br>(MIKE11) | Topographical map<br>Boundary conditions<br>Digitized river/canal network<br>River/canal cross sections | M, Overland Manning no.<br>D , Detention storage<br>L, leakage coefficient<br>M, River/canal Manning no. |
| MIKE SHE IRR – Irrigation module | Irrigated areas<br>Irr. sources (pumps/canals/reservoirs)<br>Distribution method (sheet, sprinkler, drip)<br>Source capacity | Eact/Epot, crop water stress factor (target ratio between actual and potential evapotranspiration rates) |

**Table 1** *List of model input and parameters for MIKE SHE*

The hydrological regime and thus the water balance of the Caloosahatchee basin is characterized by relatively high rates of rainfall (approximately 60 inches/year (1500 mm/year)) and evapotranspiration (pan evaporation of approximately 79 inches/year (2000 mm/year)). The evapotranspiration is the dominant factor of the water budget with or without irrigation. The infiltration capacity of the soils is high and the net rainfall recharges the water table aquifer. The flow in the water table aquifer is in general directed towards the numerous canals and ditches. Due to partly the hydraulic contact between surface water bodies and the upper aquifer sequence and partly the dense drainage networks the shallow groundwater seeps into the canals.

The moderate fluctuations of the ground water table indicate a relatively low storage capacity in the aquifer.

The number of parameters and possible combinations is large for distributed models. It is thus imperative to restrict the parameters subject to modification during the calibration and to the extent possible define ranges of the individual parameters applied to obtain a successful calibration. Within each model component the primary parameters must be specified and parameter intervals (minimum and maximum values) specified from measured field data and general characteristics of the model area.

| **Model component** | **Calibration parameters** | **Parameter range** |
|---|---|---|
| MIKE SHE SZ – Saturated zone flow | $K_h$ Horisontal hydraulic conductivity<br>$K_v$ Vertical hydraulic conductivity<br>Drainage time constant | Determined from pump test transmissivity data<br><br>$0.01 < K_v/K_h < 1.0$ |
| MIKE SHE UZ – Unsaturated zone flow | $pF_{fc}$ Capillary pressure at field capacity<br>n Exponent of hydraulic conductivity curve | $1.0 < pF_{fc} < 2.0$<br><br>$5.0 < n < 20.0$ |
| MIKE SHE ET – Evapotranspiration | Aroot :Root mass parameter<br>$K_c$ : Crop coefficient | 0.8-1.2<br>0.7-1.2 |
| MIKE SHE OC – Overland and river/canal flow (MIKE11) | M, Overland Manning no.<br>D , Detention storage<br>L, leakage coefficient<br>M, River/canal Manning no. | 1-10 m1/3/s<br>0.03 ft (0.01 m)<br>1e-3 – 1e-7 s-1<br>20-30 m1/3/s |
| MIKE SHE IRR – Irrigation module | $E_{act}/E_{pot}$, crop water stress factor (target ratio between actual and potential evapotranspiration rates) | 0.90 - 1.00 |

**Table 2** Primary parameters to be adjusted during calibration

# 3 CALIBRATION PERIOD

In order to ensure that the set of parameters applied in the model applies to both dry and wet conditions the model is calibrated for a period with both dry and wet years. 1986-1989 includes both wet and dry conditions. Due to the changes in the watershed from the late the late eighties until today the land use data have been updated to simulate the period 1994-1998. The model parameters will remain unchanged for the two periods. Changes in land use will be incorporated in the model to verify, at the same time, whether the model calibration carried out for the period 1986-1989 may be regarded valid for the entire period 1986-1998 and if the model is capable of simulating the ongoing land use change in the basin.

The irrigation canal network and groundwater wells locations are assumed identical for the two calibration periods implying that the irrigation canal system, but not necessarily the irrigation water demand, is unchanged.

## 3.1 Calibration Targets

Field measurements constitute the primary calibration references. In the Caloosahatchee model river/canal discharges and groundwater levels are used to calibrate the model. The time series of observed potential heads have been collected as part of the ground water flow models for Lee, Hendry and Glades County. They have been assigned to the deep and shallow aquifers respectively (water table aquifer and sandstone aquifer) from the well screens.

All of the available observation wells are located in the southern part of the model area. 12 shallow wells and 12 deep wells are found inside the model area.

Discharges have been recorded at the Caloosahatchee canal at Moorehaven, Ortona and Franklin lock (S-77, S-78 and S-79). Moreover discharges have been measured at Canal 19 at S-342, S-47b and S-47d.

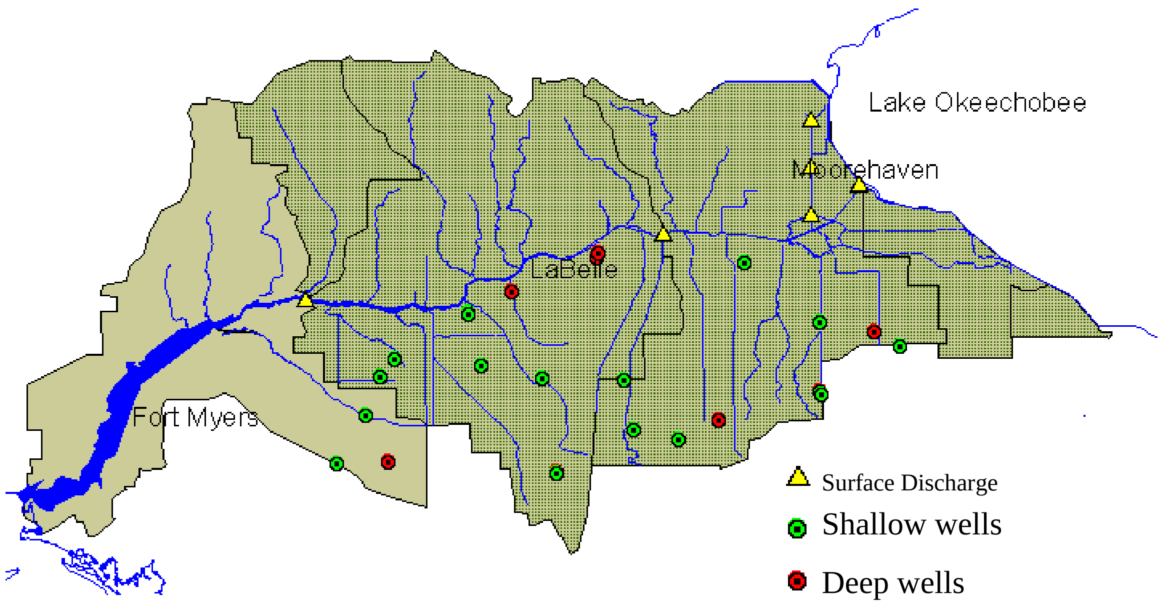


**Figure 1** *Calibration references for the Caloosahatchee Basin Integrated Surface – Groundwater model*

From the location of gauging stations and observation wells it is evident that anticipated accuracy of the model must be higher south of Caloosahatchee basin than in the northern part of the model area. Consequently calibration targets only apply to the southern part of the basin. The lack of calibration references is likely to affect the calibration against downstream total discharge from the model area in S-79 because the run off from the northern part of the area can not be checked against field measurements.

## 3.2 Numerical criteria

Numerical criteria to provide objective statistical measures of fit between the simulated and observed variables of the numerical model. Numerical criteria must be indicative of where and when the model fails to meet predefined calibration targets.

Numerical criteria should apply to the individual observed time series and describe the required accuracy as the maximum percentage of the simulation period where a predefined deviation is exceeded.

Field data are collected at a number of locations throughout the model area. The numerical criteria that the model provides reasonable results compared to the application of the model in impact assessments

During the project "Developing a Small Scale Integrated Surface Water and Groundwater Model for the South Florida Hydrogeologic System"carried out for the South Florida

Water Management District by Danish Hydraulic Institute a set of improved model calibration utilities were developed. The utility calculates

1. Read the observed ground water levels $H_{obs,i,j}$
2. Retrieve the simulated ground water levels $H_{sim,i,j}$ from a MIKE SHE simulation result file, making interpolations in space and time to the extent possible to match the time and space points where observed data are available.
3. $RES_{i,j} = H_{obs,i,j} - H_{sim,i,j} \qquad i = 1,N_{time}$ , $j = 1,N_{wells}$
4. Statistics for entire period:
   - $RES_{std,j}$
   - $H_{obs,std,j}$
   - $H_{obs,max,j}$
   - $H_{obs,min,j}$
5. For each observation well the following four criteria are calculated:
   - $R1_j$ = Percentage of time where the absolute value of ($RES_{i,j} - RES_{std,j}$) is less than 25% of ($H_{obs,max,j} - H_{obs,min,j}$)
   - $R2_j$ = Percentage of time where $H_{sim,i,j}$ lies within the range ($H_{obs,i,j} - H_{obs,std,j}$ ; $H_{obs,i,j} + H_{obs,std,j}$)
   - $R3_j$ = Percentage of time where $H_{sim,i,j}$ lies within the range ($H_{obs,min,j}$ ; $H_{obs,max,j}$)
   - $R4_j$ = Percentage of time where $H_{sim,i,j}$ lies within the range ($H_{obs,i,j}$ - 1 foot ; $H_{obs,i,j}$ + 1 foot)
6. For the entire model area the following four criteria are calculated:
   - R1 = Average over all $N_{wells}$ observation wells of $R1_j$
   - R2 = Average over all $N_{wells}$ observation wells of $R2_j$
   - R3 = Average over all $N_{wells}$ observation wells of $R3_j$
   - R4 = Average over all $N_{wells}$ observation wells of $R4_j$

The R1,R2,R3 and R4 criteria are not universally valid statistical criteria, which will ensure a satisfactory calibration in any model set up. The do, however, represent objective numerical criteria which normally are indicative of calibration accuracy. Experiences with the criteria in model calibration suggest that the following ranges should be considered appropriate in a regionale model:

| Statistical criteria | Proposed range |
|---|---|
| $R1_j$ | 0.75 |
| $R2_j$ | 0.75 (*) |
| $R3_j$ | 0.75 |
| $R4_j$ | 0.75 |
| R1 | 0.75 |
| R2 | 0.75 (*) |
| R3 | 0.75 |
| R4 | 0.75 |

(*) The R2 criteria is not applicable on regional model scale. The model simulates the average groundwater level within a 1500 ft by 1500 ft grid square, which may not represent the variation caused by e.g. abstractions.

**Table 3** Ranges of statistical calibration criteria

The criteria listed in Table 3 should be regarded as calibration targets, i.e. if the input data, the number of observation wells and the individual observation time series allow it the calibration should be continued until the criteria are met. In general the model should describe the average level and the dynamics of the groundwater table fairly accurately. The criteria may serve to check if the deviations between simulation and observation have been sufficiently reduced.

The above listed criteria are applicable to the calibration of groundwater tables. For the surface water discharges a close agreement between measured and simulated flow should be obtained in terms of:

- High flows in general
- Flow recession and low flows
- Accumulated discharge

The high flows correspond to river discharges following high intensive rainfall in the basin. The exact peak flow during single extreme events may not be captured in the model.

The model should simulate the recession in flows following discharges of large volumes of storm water.

Through periods characterised by little or no rain the flow and water levels will stabilize in the primary and secondary canals and the flow is dominated by the irrigation water demands and the control structures operated to distribute the water. The dry situation must be simulated in terms of the approximate minimum flows.

The requirement to simulate the accumulated flow in the main canal serves to ensure a correct water budget of the basin and the sub-basins contributing to S-78 and S-79.

## 3.3 'Soft' calibration references

Apart from field measurements the model may be evaluated from a more general view. The 'soft' calibration references could include:

- Aerial photos of flooding.
- Irrigation water demand
- Water balance

The model results are evaluated from the general knowledge and understanding of the model area. As no 'hard' data in terms of measurements exist the comparison between simulations and the field conditions is qualitative implying the overall pattern and performance of the hydrological system is checked against the common conception of the basin at SFWMD.

The first phase of the Caloosahatchee Basin Integrated Surface –Groundwater model aims at establishing a regional model for the freshwater part of the basin in a 1500 ft computational grid. It is thus only possible to compare model results with field conditions on the coarser scale. Hence, the lumped nature of model input and parameters on to a 1500 ft grid does not support interpretation on a detailed local scale. By decreasing the grid scale in a local model it is, however, possible to analyze the model area in further detail.

# 4 VALIDATION

Calibration is carried out for a period representing different hydrological conditions. Validation serves to test whether the set of parameters selected during the calibration are in fact suitable to represent a different period. In the present project the period 1986-1989 has been selected as calibration period and the period 1994 – 1998 as validation period. In principle the model should remain unchanged for the two periods, but given the changes in land use some modifications are required to properly represent the two periods.

# 5 SENSITIVITY ANALYSIS

The purpose of an sensitivity analysis is to determine model parameters and model inputs which are of primary importance to the model results. Input data or parameters which are considered crucial to the model results may be varied to see the effect. By carrying out a series of model runs varying the parameter or input data within given ranges a general overview of the models sensitivity is established. If the model results are particularly sensitive to a specific parameter or input type the model results should be interpreted with the uncertainty associated with this particular parameter accordingly.

The Caloosahatchee Basin Integrated Surface –Groundwater model is applied to estimate the water budget and the stress on the resource caused by irrigation. Looking at the overall water balance it is clear that evapotranspiration accounts for the largest water loss from the model area. It is thus essential to simulate the actual evapotranspiration. Accurate calculation of actual evapotranspiration depends both on the input data and the model parameters.

The input time series of potential evaporation and how well the data represents the variability within the watershed will affect the entire water budget. Model parameters of leaf area index, root depth and hydraulic properties of the soil are some parameters controlling the actual evapotranspiration rate. The availability of water in the root zone is affected by a number of factors.

The purpose of irrigation is to increase the actual transpiration rate. The irrigation demand is generated from deficit in actual evapotranspiration rate.

# 6 MODEL UNCERTAINTY

A numerical model will be associated with uncertainty. It is desirable to quantify the uncertainty in order to interpret model results in a wider context as part of water management. In an integrated and distributed model it is difficult to assess the effect of single inputs or parameters on the different results from the model. Uncertainty should be regarded as specific to a certain output of the model.

The deviations between simulated and observed may add to the uncertainty when interpreting scenario results in absolute values. When interpreting the model results of a scenario relative to a base scenario, i.e. the difference between two sets of simulation results, the uncertainty originating from the approximate agreement between model simulation and field data in the calibration, is minimised. This approach should be applied in impact analysis.